

Project Category: Freshwater

Project Title: Modeling climate change effects on the hydrology of Pacific Northwest wetland ecosystems

Principal Investigator: Dr. Alan F. Hamlet, University of Washington, Climate Impacts Group, Department of Civil and Environmental Engineering, hamleaf@uw.edu, 206.616.9361

Cooperators/Partners and anticipated project contributions:

Dr. Maureen Ryan (David H. Smith Conservation Research Fellow, Western Washington University (University of Washington as of Fall 2011), maureen.ryan@wwu.edu, 360.306.8566) will assist in adapting hydrologic projections for ecological forecasting applications.

Dr. Regina Rochefort (Science Advisor, North Cascades National Park and National Park Service contact for North Cascades Adaptation Partnership, Regina_Rochefort@nps.gov, 360.854.7202) will facilitate integration of resource managers into data review, testing for applicability, and implementation.

Dr. Lara Hansen (Executive Director, EcoAdapt, lara@ecoadapt.org, 206.201.3834) will facilitate connections between project and regional climate adaptation efforts in the Pacific Northwest.

Project Summary: This project will develop hydrologic projections for diverse wetland habitats (e.g. forest wetlands, wet meadows, small ponds, and riparian wetlands) in the Pacific Northwest (PNW) for the 2020s, 2040s, and 2080s, which can be used to support ecological and landscape-based vulnerability assessments and climate change adaptation planning. The project leverages existing downscaled climate model scenarios and associated hydrologic datasets developed under separate funding and extends them to examine changes in aquatic habitat. Products developed in this research include new hydroclimatic datasets for assessing changes in the hydroperiod of PNW wetlands. These products will be immediately useful to land managers in forecasting ecosystem responses and resilience to climate change in our proposed study areas, and will provide new tools for assessing changes in wetlands at the landscape scale over a larger domain in future studies. Databases and reports will be made publicly available on the Columbia Basin Climate Change Scenarios website at [<http://www.hydro.washington.edu/2860/>] and via collaborative partnerships with the University of Washington Climate Impacts Group [<http://cses.washington.edu/cig/>] and EcoAdapt [<http://www.ecoadapt.org>].

Project Proposal

Background and Need: Climate change is arguably the greatest conservation challenge ever encountered by the ecological management community¹⁻⁸. Local governments and land management agencies are being asked to systematically assess vulnerability of terrestrial and aquatic ecosystems to climate change impacts, and to develop sustainable adaptation strategies to mitigate projected impacts. These activities are generally hindered by lack of appropriate information and data resources for decision-making⁹. This project will develop hydrologic projections of climate change impacts on wetlands across three large areas of the Pacific Northwest, incorporating the uncertainties inherent in climate change projections, and the effects of wetland response for different land cover classes. These products are not currently available and are badly needed to help develop targeted climate adaptation strategies for a broad range of species reliant on wetland habitats, and to prioritize landscapes for conservation action.

Near-coastal areas in Pacific Northwest (PNW) are among the most sensitive regions in the western U.S. to climate change¹⁰⁻¹⁷. Projected climate change impacts in the PNW include warming in all seasons, increasing precipitation in fall, winter, and spring, and decreasing precipitation in summer²⁵. Hydrologic modeling studies have shown that such changes would result in loss of mountain snowpack, earlier peak streamflows, earlier soil moisture recharge in winter, increased soil moisture stress in late summer, and decreasing river levels during summer low flows^{18,20-26,43}. We hypothesize that these changes in hydrologic response will result in systematic changes in the timing and duration of water availability in PNW wetlands that can be successfully characterized in hydrologic modeling studies.

National Park Service (NPS), US Geological Survey (USGS), and US Forest Service (USFS) documents clearly identify a need for resources to support ecological forecasting efforts, particularly for freshwater

ecosystems. In general, NPS is seeking increased capacity in forecasting climate changes at relevant scales and integrated assessments of impacts²⁷ alongside its standing mandate to minimize destruction, loss, or degradation of wetlands (Director's Order 77.1 and Executive Order 11990). This project addresses 2 of 6 science directions in the *USGS Science Strategy*²⁸: "Understanding ecosystems and predicting ecosystem change", and "Climate variability and change." It also responds to the need for determining climate-induced effects on aquatic and terrestrial systems, stated in the USFS Climate Change Research Strategy, by identifying "water resource attributes most [important to] aquatic and riparian species," that can be used to "[conduct biodiversity] assessments and [develop] models that predict species' response to landscape and climate changes"²⁹.

The Pacific Northwest is home to two of the three existing climate adaptation collaborations between NPS and USFS (North Cascadia Adaptation Partnership (NCAP) and Olympic Climate Change Case Study³⁰). These existing partnerships provide an excellent framework for cross-agency communication and implementation, and both collaborative groups have expressed strong interest in the products that we propose to develop^{31,32}. This project will also provide information support for existing federal programs and evaluations such as Watershed Vulnerability Assessments (USFS; pilots underway in regions outside of the Pacific Northwest) by enabling ecological forecasting of impacts on aquatic species, and will supplement mandated Watershed Condition Analysis (required of all national forests in 2011), National Resource Condition Assessments, and integration of climate change forecasts into the Northwest Forest Plan.

The ultimate goal of this project is to produce resources to support decision-making in the development of climate adaptation strategies that maintain viable existing populations and build adaptive capacity³³ for the future^{34,35}. We are already working with managers at NPS and USFS to build connections among multi-disciplinary researchers and managers, and to collectively define management challenges to which outputs (hydrologic projections) from this project can be applied, as recommended by NPS²⁷. Applications identified thus far include identification of regions where direct threats of hydrologic change are greatest, e.g. wetland loss and its effects on animal and plant distributions, including invasive species, and assessments of habitat connectivity and fragmentation for aquatic and non-aquatic species reliant on wetland habitats. Hydrologic projections can also be used to identify regions where changing climate is forecasted to exacerbate existing ecosystem vulnerabilities. One of the immediate uses of the hydrologic projections developed through this project is in identifying regions where currently stable amphibian populations are likely to be "squeezed" between climate-induced drying of temporary wetland habitats and the presence of introduced trout, which exclude amphibians from deeper climate-change-resistant lake and pond habitats.

Objective: This project directly contributes to several of the stated goals of the North Pacific Landscape Conservation Cooperative: 1) to apply downscaled climate models at landscape scales to predict effects on fish, wildlife, plants and their habitats, 2) to assess watershed resiliency with changing wetland hydroperiods to inform restoration investments, and 3) to support risk and vulnerability assessments that identify the most sensitive species, habitats and ecological functions. Specifically, the project itself will directly assess effects to surface water availability in wetlands over two areas of the Pacific Northwest, and the hydrologic projections developed through this project will provide substantial decision support for managers tasked with conserving wetland ecosystems. In a separately funded study and collaborative effort with NCAP and Olympic National Park and Forest, Maureen Ryan will use the hydrologic projections from this project to conduct a vulnerability assessment of wetland ecosystems in the Pacific Northwest and to develop decision support tools for managers tasked with prioritizing regions for fish removals, as part of a new climate adaptation strategy for wetland communities.

Methods: We will use data from a series of recent hydrologic modeling studies (PI Hamlet)^{43,47} to investigate the effects of climate change on wetland hydrology in the Olympic National Park & National Forest (OLYM/OLNF), North Cascades National Park (NOCA), and Mt. Rainier National Park (MORA). We broadly define wetlands as areas where shallow surface water collects, providing habitat for aquatic species such as amphibians, invertebrates, birds, and fish.

Part 1. Climate predictions: The University of Washington Climate Impacts Group (CIG) has produced regionally downscaled climate data for the PNW, based on global climate model (GCM) simulations assembled

for the fourth IPCC assessment^{25,36}. From the 77 available scenarios, we will use an ensemble of 10 scenarios based on the A1b emissions scenario and the *Hybrid Delta* Downscaling technique⁴⁸ for three future time periods, the 2020s, 2040s and 2080s. These meteorological driving data sets have already been coupled to the VIC hydrologic model described below, and are available to this project at no cost.

Part 2. Hydrologic projections: We will use existing hydrologic databases produced by CIG as a part of recent climate change assessments (PI Hamlet, <http://www.hydro.washington.edu/2860/>) for the A1B emissions scenario for the 2020s, 2040s and 2080s to project hydrologic conditions associated with each GCM scenario. In particular we will use simulations of ecologically relevant water balance variables (such as spring/summer precipitation, snowpack, soil moisture, moisture deficit (PET-AET), and runoff) from the Variable Infiltration Capacity (VIC) macroscale hydrologic simulation model implemented at 1/16th degree resolution^{43,47} to generate empirical models of wetland response for different land cover classes (e.g. forest wetlands, open meadows, riparian areas) across the landscape of the Pacific Northwest (Figure 1).

These combined physical/empirical models will be matched with complementary fine-scale Distributed Hydrology Soils and Vegetation Model (DHSVM) implementations over smaller domains (developed under separate funding to Dr. Ryan), which will provide enhanced representation of fine-scale topographic features and hydrologic processes that contribute to wetland response.

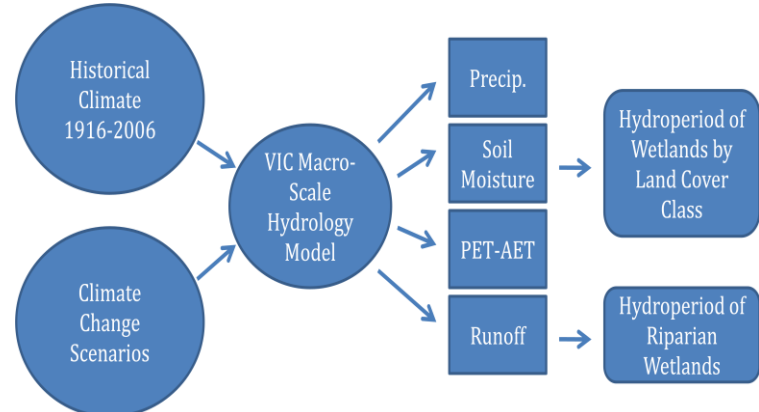


Figure 1. Schematic diagram of hydrologic modeling and predictors for aquatic habitat metrics

Part 3. Relating hydrologic water balance simulations to wetland response: Wetlands are a function not only of hydrology but also topography, geomorphology, vegetation cover, and soil characteristics. Our approach will be to empirically relate simulations of water balance variables such as precipitation, snowpack, near-surface soil moisture, moisture deficit (PET-AET) and runoff to observed patterns of surface ponding and wetland inundation for different land cover classes, creating indices for wetland inundation timing and duration (Figure 1). This approach is analogous to successful past collaborative efforts which have related hydrologic water balance variables to forest growth and disturbance over diverse landscapes^{38,49}. We will also relate runoff projections to inundation of riparian areas, using the mean annual flood (a proxy for bank-full flow) as a predictor for riparian inundation events. These approaches will be validated using empirical data, existing maps and databases of wetlands from NPS and USFS (e.g. from the National Wetland Inventory), as well as newly collected data in a concurrent study (Maureen Ryan, under separate Smith Fellowship funding) over diverse landscapes within the study area.

Part 4. Hypotheses: We hypothesize that projected changes in the timing and quantity of surface water availability associated with climate change will translate into systematic shifts in the timing and duration of inundation of PNW wetlands, resulting in higher water levels in winter and early spring due to elevated soil moisture, a more rapid recession of water levels in spring, and reduced water levels in summer.

Part 5. Stakeholder process and symposium: We are already engaged in a stakeholder process that includes NPS, USFS, USGS, EcoAdapt, and academic partners to identify management goals and outputs. In addition to this ongoing process, we will organize a symposium in collaboration with EcoAdapt, which will provide a forum for introducing and receiving feedback on management resources, and for establishing further connections across institutional boundaries.

Final products & outputs: Outputs include raw hydroclimatic datasets of daily, weekly, and monthly projected water balance variables as well as maps coding severity of projected change in hydroperiod for wetlands in different land cover classes for the 2020s, 2040s, and 2080s. These products will provide critical forecasts of climate change effects on a major environmental driver (surface water availability) and critical habitat types (wetlands) and will support effective conservation delivery by providing management-designed resources for decision making in the near- and long-term. The proposed research will also provide new tools for estimating wetland impacts associated with climate change scenarios that can be extended to other areas in the western U.S. and Canada.

Applications: Hydrologic projections can be used by or would supplement Natural Resource Condition Assessments (NRCA). This will be particularly valuable to Olympic National Park, which will start their NRCA within the next two years. Mount Rainier and North Cascades National Parks are currently conducting their assessments and would have immediate need for these products.

Key Cooperators: Dr. Hamlet developed the hydrologic databases that we will adapt for this project and has been extensively involved in studies of climate impacts on water resources, vulnerability assessments of aquatic ecosystems, and regional adaptation planning in the Pacific Northwest^{12,13,17-21,39-46}. Dr. Rochefort is the primary NPS contact for the NCAP program and will facilitate communication and implementation with land managers. She will provide in-kind salary support (\$10K). Dr. Hansen has worked in climate change research for 20 years and is the founder of EcoAdapt, which assists in the development and implementation of adaptation strategies in response to climate change. She is currently working in the Pacific Northwest region and beyond with conservation organizations, government agencies and universities, and has collaborated with Dr. Hamlet and local conservation organizations on developing adaptation strategies for watersheds in the North Cascades and Olympic Peninsula. She has extensive experience with climate change vulnerability assessments, in convening symposia and workshops for engaging stakeholders, and in developing strategies that are both effective and palatable for the implementing community. She will provide in-kind salary support (\$10K). Dr. Ryan is currently a David H. Smith Conservation Research Fellow with the Society for Conservation Biology, and her research focuses on developing a climate adaptation strategy for Pacific Northwest wetland ecosystems in collaboration with the National Park Service and US Forest Service. She will facilitate the development of products for direct application to ecological forecasting. Using leveraged funds, Dr. Ryan will also immediately use hydrologic projections as part of a climate adaptation strategy for wetland species currently in development in collaboration with the National Park Service and US Forest Service (project funded by the David H. Smith Conservation Research Fellowship). The Smith Program will provide matching salary support (\$50K) and research funds (\$40K) for Dr. Ryan's involvement in this project.

Geographic Extent: Focal areas are Olympic National Park & National Forest, North Cascades National Park, and Mt. Rainier National Park, but development of tools will support entire NPLCC domain.

Timeline of Schedules, Products, and Outcomes: *Fall 2011-Winter 2012:* Adapt existing VIC model simulations for surface wetland applications. *Spring 2012:* Test and refine empirical models using existing wetland maps and empirical data. *Summer 2012:* Make preliminary maps and projections available to NCAP and Olympic NP/NF to integrate resource managers into data review and test for applicability. Refine models as needed. Prepare final report. *Fall 2012:* Hold 2-day symposium for managers with USFWS, NPS, USFS, NGOs, and municipal representatives.

Disclaimer regarding Data Sharing There are no restrictions on data sharing from this project. All CIG products are currently available to the public on a website (<http://www.hydro.washington.edu/2860/>). New data products generated through this research will be made available on this website. We will maintain simulation data for five years, and archive source code for ten years. Publications will make methods and information resources available to the scientific community. Ryan and Hansen will also organize a symposium to discuss use of hydrologic products in biodiversity vulnerability assessments and direct applications for wildlife management.

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Budget Summary:

Requested funding is \$99,829 spread over 15 months. The University of Washington is partner in an existing CESU agreement that limits institutional overhead to 17.5%.

Leveraging: This project builds upon hydroclimatic datasets produced for streamflow applications and adapts them for surface wetland applications, expanding the availability of downscaled climate-driven hydrologic layers. Total in-kind contributions include UW post-doc office space and UNIX servers (Hamlet: \$25K) and salary contributions by unfunded cooperators (Hansen: \$10K, Rochefort: \$10K). Matching funds include fellowship funds to Maureen Ryan through the David H. Smith Conservation Research Fellowship (\$40K research, \$50K salary).

SECTION	ITEMIZED	Year 1 (12 months)	Year 2 (3 months)
Principal Investigator Salary & Benefits	Hamlet	\$9396.00	
RA Salary & Benefits	UW Post-doc	\$62544.00	
Contracts			
Travel			
Publication Costs			
Equipment	Desktop computer (no indirect cost)	\$1200.00	
Materials and Supplies			
Services	Year 2 Workshop Year 2 Web services		\$10000.00 2000.00
			Totals for Year1 + Year2
Total Direct Costs			\$85140.00
Indirect Costs (Overhead)**	17.5%		\$14689.00
Funds Requested (Direct + Indirect)			\$99829.00
Partner Contributions			
UW Office Space and UNIX Computers	\$25,000 (in-kind)		
EcoAdapt Hansen Salary	\$10,000 (in-kind)		
National Park Service Rochefort Salary	\$10,000 (in-kind)		
Smith Fellowship Ryan Salary	\$50,000/yr (matching)		
Research Funds (data collection)	\$40,000 (matching)		
Total value of partner contributions	\$135,000		

**The University of Washington is partner in an existing CESU agreement that limits institutional overhead to 17.5%.

Resumes:

Curriculum Vitae Alan F. Hamlet (PI)

Professional Preparation:

Ph.D. in Civil and Environmental Engineering, University of Washington, 2006
MSE in Civil and Environmental Engineering, University of Washington, 1996
BS in Mechanical Engineering, University of Washington, 1992
BA in Mathematics, University of Rochester (NY), 1981

Appointments:

Research Assistant Professor, CEE, University of Washington, 2007-present
Research Scientist, CSES Climate Impacts Group, UW, 1996-present

Research Interests:

Land surface hydrology and modeling
Flooding and assessment of hydrologic extremes
Impacts of climate variability and climate change on hydrology and water resources
Sustainable water resources management and climate change adaptation strategies
Modeling of freshwater and estuarine ecosystems
Forest hydrology and impacts to terrestrial ecosystems
Paleoclimatic precipitation and streamflow reconstruction

Selected Publications Most Closely Related to the Proposal:

Crozier, L., R.W. Zabel, A.H. Hamlet, 2007: Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon, *Global Change Biology*, 14 (2): 236-249
Hamlet, A.F., Mote, P.W., Clark, M.P., Lettenmaier, D.P., 2005: Effects of temperature and precipitation variability on snowpack trends in the western U.S., *J. of Climate*, 18 (21): 4545-4561
Hamlet, A.F., Mote, P.W., Clark, M.P., Lettenmaier, D.P., 2007: 20th Century Trends in Runoff, Evapotranspiration, and Soil Moisture in the Western U.S., *J. Climate*, 20 (8): 1468-1486
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Wenger, S. J., C. H. Luce, A. F. Hamlet, D. J. Isaak, and H. M. Neville, 2010:, Macroscale hydrologic modeling of ecologically relevant flow metrics, *Water Resources Research*, 46, W09513, doi:10.1029/2009WR008839

Additional Relevant Publications:

Hamlet, A.F., Lettenmaier, D.P., 1999: Effects of Climate Change on Hydrology and Water Resources in the Columbia River Basin, *J. of the American Water Resources Association*, 35 (6): 1597-1623

Hamlet, A.F., 2011: Assessing water resources adaptive capacity to climate change impacts in the Pacific Northwest region of North America, *HESS* (in press)

Lee, S-Y., A. F. Hamlet, C. J. Fitzgerald, and S. J. Burges, 2009: Optimized Flood Control in the Columbia River Basin for a Global Warming Scenario, *Journal of Water Resources Planning and Management*, DOI 10.1061/(ASCE)0733-9496(2009)135:6(440), 135(6) 440-450

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Mote, P.W., E.A. Parson, A.F. Hamlet, K.G. Ideker, W.S. Keeton, D. P., Lettenmaier, N.J. Mantua, E.L. Miles, D.W. Peterson, D.L. Peterson, R., Slaughter, and A.K. Snover, 2003: Preparing for climatic change: the water, salmon, and forests of the Pacific Northwest, *Climatic Change*, 61: 45-88

Mote P.W., Hamlet A.F., Clark M.P., Lettenmaier D.P., 2005: Declining mountain snowpack in western North America, *BAMS*, 86 (1): 39-49

Synergistic Activities:

Founding member of the interdisciplinary Skagit Climate Science Consortium (fostering interdisciplinary climate research in the Skagit River basin)

Fifteen years of active participation in the Climate Impacts Group's internationally recognized outreach, education, and adaptation programs (typically 30 presentations per year at conferences, meetings, workshops).

Member of the advisory board for the Columbia Basin Trust's *Communities Adapting to Climate Change* program in British Columbia (2008-present)

K-12 hydrology outreach and education, targeting classroom demonstrations and teacher preparation workshops using a simple physical hydrologic model (2006-present)

Biographical Sketch Maureen E. Ryan

Western Washington University
Fairhaven College
516 High Street
Bellingham, WA 98225
Email: ambystomo@gmail.com
Telephone: 530.304.2266

Professional preparation

Georgetown University (1991-1995)	English	BA, 1995
University of Wyoming (2001-2002)	Biology	postbaccalaureate studies
University of California Santa Cruz (2003)	Mathematics	postbaccalaureate studies
University of California Davis (2003-2010)	Population Biology	PhD, 2010
University of Washington (2011-2013)	Conservation Research	Postdoctoral Fellow

Professional employment and appointments

2011-2013	David H. Smith Conservation Research Fellow, Society for Conservation Biology, University of Washington; project titled "Restoring resilience to climate change."
2010-2011	Instructor, Fairhaven College, Western Washington University
2009	Graduate research assistant for Dr. Bradley Shaffer for project identifying conservation targets using integrodifference models.
2008, 2009	Contracted by California Department of Fish and Game to study landscape and genetic influences on amphibian species interactions in central California.
2007	Instructor for undergraduate seminar, "The Human Animal" (2 quarters).
2006-2008	Environmental Protection Agency STAR Fellow, research focused on amphibian community ecology and conservation.
2006	Graduate teaching assistant for <i>Herpetology</i> .
2004	Graduate teaching assistant for <i>Evolution</i> (2 quarters).
2002	Research assistant for Dr. Erin Muths, United States Geological Survey, Laramie, WY.
2001-2003	Research assistant for Dr. David McDonald, University of Wyoming.
2000-2001	Research assistant for Robert Prescott, Massachusetts Audubon Society, Wellfleet, MA.

Publications

Ryan ME, Johnson JR, Fitzpatrick BM. 2009. Invasive hybrid tiger salamander genotypes impact native amphibians. *Proceedings of the National Academy of Sciences* 106 (27): 11166-11171.

Schreiber SJ, Ryan ME. 2010. Speed of invasion for structured populations in fluctuating environments. *Theoretical Ecology*. *In press*.

Ryan ME. 2010. Ecology of amphibian hybridization in a changing landscape. PhD Dissertation.

Ryan ME, Johnson JR, Fitzpatrick BM, Lowenstine LJ, Picco AM, Shaffer HB. *In revision*. Agricultural landscape favors introduced hybrid salamanders over threatened California salamanders. *Conservation Biology*.

Ryan ME, Bobzien S, Trenham PC, Shaffer HB. *In revision*. Aquatic habitat structure influences survival of threatened California Tiger Salamanders and their interactions with native amphibians. *Biological Conservation*.

Manuscripts in preparation

Ryan ME, Chesson PL. *In final preparation*. Environment-competition interactions in an invaded amphibian assemblage. Will submit to *Ecology*, June 2011.

Ryan ME, Chesson PL. *In preparation*. Animal movement patterns influence population growth: theory and practice in amphibian populations.

Ryan ME, Schreiber S, Shaffer HB. *In preparation*. Identifying key conservation targets using integrodifference models: a case study of a tiger salamander hybrid zone.

Grants, Fellowships and Awards

2011 – David H. Smith Conservation Research Fellowship (\$141,000)
2008-2009 – California Department of Fish and Game, Research Grant (\$18,334)
2006-2008 – Environmental Protection Agency, STAR Graduate Research Fellowship (\$101,909)
2007 – University of California Davis, Undergraduate Instructional Improvement Program (\$3,500)
2003-2009 – University of California Davis Block Grant, 6 quarters (\$30,000 plus benefits)
2004-2008 – University of California Davis, Center for Population Biology, Research Awards (\$4,705)
2005-2008 – University of California Davis, Center for Population Biology, Travel Awards (\$1,300)
2005-2006 – Daphne & Ted Pengelley Research Award (\$500)
2005 – Achievement Rewards for College Scientists Foundation, Research Award (\$5,000)
2002 – National Science Foundation, EPSCoR Fellowship (\$2,000)

Synergistic Activities

1. Conservation & Management. I am currently developing a climate adaptation strategy for western Pacific Northwest wetland ecosystems in collaboration with Alan Hamlet at the University of Washington Climate Impacts Group, Wendy Palen at Simon Fraser University, biologists and land managers at the National Park Service and US Forest Service, and biologists at the US Geological Survey. My doctoral research was focused on conservation and management of central California amphibian assemblages. I have co-taught professional workshops on the biology & conservation of California Tiger Salamanders, contributed to endangered species assessments for US Fish and Wildlife Service and California Department of Fish & Game, and implemented conservation actions with Bureau of Land Management.

2. Teaching & undergraduate training. I am currently teaching at Fairhaven College, taught interdisciplinary undergraduate seminars at UC Davis, and have trained >15 undergraduate research assistants, including many from groups traditionally underrepresented in the sciences.

3. Community outreach. I am engaged in developing a stakeholder process associated with wetland climate adaptation for the Pacific Northwest national parks and forests. I also currently work with the Whatcom Land Trust on conservation education initiatives and am a contributor to Readthedirt.org, an online publication focused on Pacific Northwest natural resources, land management, and ecology. In California, I conducted a large-scale analysis of amphibian habitat use for the East Bay Regional Park District, trained prospective Federal Recovery Permittees in handling and identification of endangered amphibians in California, conducted free surveys for landowners and a local land trust, and assisted in surveys for endangered species with the Bureau of Land Management.

4. Broader impacts. My recent publication in PNAS garnered considerable public interest and was written up in the New York Times (Science Times), San Francisco Chronicle, and National Geographic News.

Collaborators and other affiliations

Jarrett Johnson, University of Western Kentucky
Benjamin Fitzpatrick, University of Tennessee
Peter Chesson, University of Arizona
H. Bradley Shaffer, UC Davis
Alan Hamlet, University of Washington
Karen Pope, US Forest Service
Steven Bobzien, East Bay Regional Park District
Lara Hansen, EcoAdapt

Jonah Piovia-Scott, UC Davis
Sharon Lawler, UC Davis
Linda Lowenstine, UC Davis
Wendy Palen, Simon Fraser University
Michael Adams, Oregon State University
Justin Garwood, CA Dept of Fish & Game
Nicholas Dulvy, Simon Fraser University
Angela Picco, US Fish & Wildlife Service

Curriculum Vitae

Regina M. Rochefort, Ph.D.

North Cascades National Park
2105 State Route 20
Sedro-Woolley, WA 98284
(360)854-7202
e-mail: regina_rochefort@nps.gov

EDUCATION

- 1995 Ph.D. Ecosystems Analysis. College of Forest Resources, University of Washington, Seattle, Washington.
- 1978 M.F.S. School of Forestry and Environmental Studies, Yale University, New Haven, Connecticut.
- 1975 B.S. Biology. Northeastern University, Boston, Massachusetts.

PROFESSIONAL EXPERIENCE

- 1998- present Science Advisor, North Cascades National Park Service Complex. Responsibilities: identifies and facilitates research needs in Pacific Northwest National Parks; technical advisor on research related to plant ecology, ecosystem restoration, and climate change; coordinates park efforts to develop climate adaptation strategies.
- 1999- present Affiliate Assistant Professor, School of Forest Resources, College of the Environment, University of Washington
- 1984-1998 Botanist, Mount Rainier National Park. Responsibilities: developed and implemented the park's first plant ecology program including vegetation and soil restoration and long-term monitoring of alpine plant communities.
- 1982- 1984 Botanist, Everglades National Park. Responsibilities: monitored fire effects and behavior, developed Exotic Plant control program
- 1979- 1982 Ecologist, South Florida Research Station, Everglades National Park. Responsibilities: established fire research program in Big Cypress National Preserve.

PUBLICATIONS

- Rochefort, R.M., M.M. Bivin, J.R. Boetsch, L. Grace, S. Howlin, S.A. Acker, C.C. Thompson, and L. Whiteaker (in press). Alpine and subalpine vegetation monitoring protocol for the North Coast and Cascades Network. NPS/NCCN/NRTR. National Park Service, Fort Collins, Colorado.
- Rochefort, R. M. and M. M. Bivin. 2010. Vascular plant inventory of San Juan Island National Historical Park. Natural resource Technical Report NPS/NCCN/NRTR - 2010/350. National Park Service, Fort Collins Colorado.
- Rochefort, R. M. 2010. Vascular plant inventory of Mount Rainier National Park. Natural Resource Technical Report NPS/NCCN/NRTR—2010/347. National Park Service, Fort Collins, Colorado.

- Bivin, M. M. and R. M. Rochefort. 2010. Vascular plant inventory of North Cascades National Park Service Complex. Natural Resource Technical Report NPS/NRTR – 2010/369. National Park Service, Fort Collins, Colorado.
- Stueve, Kirk M.; Cerney, D. L. Rochefort, R. M., and Kurth, L. L. 2009. Post-fire tree establishment patterns at the alpine treeline ecotone: Mount Rainier National Park, Washington, USA. *Journal of Vegetation Science* 20: 107-120.
- Rochefort, R.M. 2008. The influence of white pine blister rust (*Cronartium rubicola*) on whitebark pine (*Pinus albicaulis*) in Mount Rainier National Park and North Cascades National Park Service Complex, Washington. *Natural Areas Journal* 28 (3): 290-298.
- Rochefort, R.M., L. Kurth, J. L. Riedel, T. Carolin, R. R. Mierendorf, K. Frappier, and D. Steensen. 2006. Mountain Ecosystem Restoration. IN : Restoring the Pacific Northwest : The Art and Science of Ecological Restoration in Cascadia. Dean Apostle and Marcia Sinclair (eds). Washington D.C., Island Press.
- Rochefort, R. M. and Peterson, D. L. 2001. Genetic and morphologic variation in *Phyllodoce empetriflora* and *P. glanduliflora* (Ericaceae) in Mount Rainier National Park, Washington. *Canadian Journal of Botany* 79: 179-191.
- Rochefort, R. M. and Swinney, D. D. 2000. Human impact survey in Mount Rainier National Park: past, present and future. In: Cole, D. N.; S. F. McColl; W. T. Borrie; and J. O’Laughlin (comps.), *Wilderness Science in a Time of Change Conference – Volume 5: Wilderness ecosystems, threats, and management*; 1999 May 23-27; Missoula, MT. Proceedings RMRS-P-15-VOL-5. Ogden, UT: U.S. Dept. of Agriculture, Forest Service, Rocky Mountain Research Station. pp. 165- 171.
- Rochefort, R. M. and Peterson, D. L. 1996. Temporal and spatial distribution of trees in subalpine meadows of Mount Rainier National Park. *Arctic and Alpine Research* 28(1): 52-59
- Rochefort, R. M.; Little, R. L.; Woodward, A.; and Peterson, D.L. 1994. Changes in sub-alpine tree distribution in western North America: a review of climatic and other causal factors. *The Holocene* 4(1): 89-100.
- Rochefort, R. M. and Gibbons, S. T. 1992. Mending the meadow: High-altitude meadow restoration in Mount Rainier National Park. *Restoration and Management Notes* 10(2): 120-126.
- Rochefort, R. M. 1989. Paradise Meadow Plan. Mount Rainier National Park, Ashford, WA.

LARA J. HANSEN

EcoAdapt ~ P.O. Box 9767, Washington, DC 20016
(206) 201-3834 ~ lara@ecoadapt.org

EDUCATION

Ph.D., Ecology, University of California, Davis	December 1998
Bachelor of Arts, Biology (marine emphasis), University of California, Santa Cruz	June 1992
Oregon Institute of Marine Biology, University of Oregon, Charleston, OR	Summer 1987
NSF Antarctic Biology Course (photobiology and adaptation of Antarctic organisms)	1998-1999

RESEARCH EXPERIENCE

Chief Scientist, Executive Director and Co-Founder, EcoAdapt	2008- present
Principal, Lara Hansen and Associates	2008-present
Chief Scientist and Director, Climate Change Program, World Wildlife Fund	2001- 2008
Post-doctoral Researcher Ecologist, Gulf Ecology Division, USEPA	1998- 2001
Doctoral Research, University of California, Davis	1992-1998
Research Scientist, Kasitsna Bay Laboratory, Seldovia, AK	April 1995
Aquatic Toxicologist, S.R. Hansen and Associates, Concord, CA	1986-1992

TEACHING EXPERIENCE

Climate Camp, Various locations 2006- present
Visiting Scholar/Lecturer, Scripps Institute of Oceanography, University of California, San Diego 2005- present
Lecturer, Johns Hopkins University, Baltimore, MD 2001- present
Adjunct Professor, Pensacola Junior College, Pensacola, FL Spring 2001

GRANTS AND FELLOWSHIPS (selected)

Kresge Foundation "Innovate and Foster Climate Change Adaptation"	2010-2012
Harder Foundation "Building Climate Change into Washington's Marine Spatial Planning Process"	2010-2011
Wilburforce Foundation "Advancing Climate Change Adaptation in Western North America"	2010-2011
Wilburforce Foundation "Building Adaptation into Western North American Conservation"	2009-2010
Kresge Foundation "Building the Community of Climate Adaptation: Ecosystems & Human Well Being"	2009-2010
Moore Foundation "The State of Marine Adaptation to Climate Change in North America"	2008-2010
Switzer Foundation Leadership Grant	2008-2009
MacArthur Foundation, World Conservation Congress Workshop for MacArthur Fundees	2008
MacArthur Foundation "Integrating Climate Change into Coastal and Marine Conservation in Madagascar"	2007-2009
Batchelor Foundation "Climate Change LEADS: Stakeholder Outreach"	2007-2009
Hewlett-Packard "Assessing Climate Change Vulnerability in the Bering Sea"	2007-2008
NOAA Grant "Climate Change LEADS: Linking Environmental Analysis to Decision Support"	2006-2008
UNEP/GEF MSP "Developing Generalizable Method for Climate Adaptive Management & Protection"	2006-2009
UK DFID "Constructing a Climate Change Adaptation Strategy for the Mesoamerican Reef"	2006-2009
NOAA Grant "Enhancing Management Effectiveness of MPAs and Coral Reef Species Conservation"	2002-2004
USEPA Cooperative Agreement on coral reef/climate change adaptation in American Samoa	2002-2004

AWARDS AND HONORS (selected)

IUCN Woman Fighting Climate Change	2007
EPA Scientific and Technological Achievement Award, Level III	2003, 2004
EPA Bronze Medal	2002
EPA Superior Accomplishment Awards (Two)	2000
Herpetologist League, Graduate Student Paper, Finalist	1997
Switzer Environmental Fellow	1995-1996

PUBLICATIONS (selected)

Hansen, L.J. and J.R. Hoffman. 2011. Climate Savvy: Adapting Conservation and Resource Management to a Changing World. Island Press, Washington DC.

- Cross, M.S., E.S. Zavaleta, D. Bachelet, M.L. Brooks, C.A.F. Enquist, E. Fleishman, L. Graumlich, C.R. Groves, L. Hannah, L. Hansen, G. Hayward, M. Koopman, J.J. Lawler, J. Malcolm, J. Nordgren, B. Petersen, D. Scott, S.L. Shafer, M.R. Shaw, and G.M. Tabor. Submitted. A climate change adaptation framework for natural resource conservation and management. *Conservation Letters*.
- Hansen, L.J., J.R. Hoffman, C. Drews and E.E. Mielbrecht. 2010. Adapting conservation to climate change. *Conservation Biology*. 24:63-68.
- Lawler, J.J., T.H. Tear, C. Pyke, M.R. Shaw, P. Gonzalez, P. Kareiva, L. Hansen, L. Hannah, K. Klausmeyer, A. Aldous, C. Bienz, and S. Pearsall. 2010. Resource management in a changing and uncertain climate. *Frontiers in Ecology and the Environment*. 8(1):35-43.
- Pittock, J., L.J. Hansen and R. Abell. 2008. Running dry: freshwater biodiversity, protected areas and climate change. *Biodiversity*. 9(3-4):30-38.
- Janetos, A., L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson and R. Shaw. 2008. Biodiversity. In: The effects of climate change on agriculture, land resources, water resources and biodiversity. Synthesis and Assessment Product 4.3: A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington DC USA, 362 pp.
- Ficke, A.D., C.A. Myrick and L.J. Hansen. 2007. Effects of global climate change freshwater fish and fisheries. *Reviews in Fish Biology and Fisheries*. 17:581-612.
- Hansen, L.J. and C.R. Pyke. 2007. Climate Change and Federal Environmental Law. *Sustainable Development Law & Policy Journal* 7(2):26-29.
- Malcolm, J.R., C. Liu, R.P. Neilson, L. Hansen and L. Hannah. 2006. Global warming and extinctions of endemic species from biodiversity hotspots. *Conservation Biology* 20(2):538-548.
- Ad hoc Technical Expert Group on Biodiversity and Adaptation to Climate Change. 2006. Guidance for Promoting Synergy Among Activities Addressing Biological Diversity, Desertification, Land Degradation and Climate Change. CBD Technical Series No. 25. Secretariat of the Convention on Biological Diversity.
- Caldiera, K., M. Akai, P. Brewer, B. Chen, P. Haugan, T. Iwama, P. Johnston, H. Kheshgi, Q. Li, T. Ohsumi, H. Pörtner, C. Sabine, Y. Shirayama, J. Thomson, J. Barry and L. Hansen (Contributing Author). 2005 In Metz, B., O. Davidson, H. DeConinck, M. Loos, and L. Meyer (editors). 2005. IPCC Special Report on Carbon Dioxide Capture and Storage. Cambridge University Press.
- J. Biringer and L. Hansen. 2005. Restoring Forest landscapes in the Face of Climate Change. In Mansourian, Stephanie; Vallauri, Daniel; Dudley, Nigel (Eds.) *Forest Restoration in Landscapes: Beyond Planting Trees*, Springer, New York.
- Hannah, L. and L.J. Hansen. 2005. Chapter 20: Conservation Responses: Designing Landscapes. In Hannah, L and T. Lovejoy (Eds.). *Biodiversity and Climate Change*. Yale University Press.
- Roessig, J.M., C.M. Woodley, J.J. Cech, Jr. and L.J. Hansen. 2004. Effects of global climate change on marine and estuarine fish and fisheries. *Reviews in Fish Biology and Fisheries* 14(2):251-275.
- Hansen, L.J., J.L. Biringer, J.R. Hoffman (editors). 2003. *Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems*. WWF.
- Hansen, L.J., S.F. Hedtko and W.R. Munns. 2003. Integrated human and ecological risk assessment: A case study of ultraviolet radiation effects on amphibians, coral, humans and oceanic primary productivity. *Human and Ecological Risk Assessment*. 9(1):359-377.
- Hoffman, J.R., L.J. Hansen, and T. Klinger. 2003. Interactions between ultraviolet radiation and temperature limit inferences from single-factor experiments. *Journal of Phycology*. 39(2): 268-272.
- Hansen, L.J., A. Whitehead and S.L. Anderson. 2002. Solar UV radiation enhances the toxicity of arsenic in *Ceriodaphnia dubia*. *Ecotoxicology*. 11:279-287.
- Anderson, S.A., R. Zepp, J. Machula, D. Santavy, L. Hansen and E. Mueller. 2001. Indicators of UV exposure in corals and their relevance to global climate change and coral bleaching. *Human and Ecological Risk Assessment*. 7(5):1271-1282
- Hansen L.J., Fabacher D.L., and Calfee R. 2001. The Role of the Egg Jelly Coat in Protecting *Hyla regilla* and *Bufo canorus* Embryos from Ultraviolet B Radiation during Development. *ESPR - Environmental Science & Pollution Research-OnlineFirst* [DOI: <http://dx.doi.org/10.1065/espr2001.10.097>] [printed in 2002, 9(6):412-416]
- Hansen, L.J. and M.B. Johnson. 1999. Conservation and toxicology: Integrating the disciplines. *Conservation Biology* 13(5):1225-1227. (Also published as Hansen, L.J. and M.B. Johnson. 1999. Conservation and toxicology: The need to integrate the disciplines. *Environmental Toxicology and Chemistry* 18(10):2121-2122).
- Datta, S, L. Hansen, L. McConnell, J. Baker, J. LeNoir and J. Seiber. 1998. Pesticides and PCB contaminants in fish and frogs from the Kaweah River Basin, California. *Bulletin of Environmental Contamination and Toxicology*. 60:829-836.